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Hon. Commissioner of Patents and Trademarks,
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SIR:

CERTIFIED TRANSLATION

I, Mariko Kayama, am an official translator of the Japanese language into the English language and I hereby certify that the attached comprises an accurate translation into English of Japanese Application No. 11-082228, filed on March 25, 1999.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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[Title of the Invention]

Image Processing Apparatus, Image Processing Method and Recording Medium

[Claims]

[Claim 1] An image processing apparatus comprising:

data acquiring means for acquiring image data representing an image composed of a plurality of pixels each having one color component of one of N fundamental colors;

class determining means for determining a class of the first image data, from the color component of the most dense pixel of the pixels of the image data; and

operation means for calculating the color component of each of the N fundamental colors, for one of the pixels represented by the image data, in accordance with the class determined by the class determining means.

[Claim 2] The image processing apparatus according to claim 1, further comprising:

a prediction tap determining means for determining a prediction tap from the pixels represented by the image data, said prediction tap predicting a prescribed pixel; and

memory means for storing prediction coefficients for predicting the

prescribed pixel of the image signal,

wherein the operation means performs calculation on the prediction tap determined by the prediction tap determining means and the prediction coefficient corresponding to the class determined by the class determining means.

[Claim 3] The image processing apparatus according to claim 2, wherein the tap determining means determines, as the prediction tap, pixels of all N fundamental colors.

[Claim 4] An image processing method comprising :

a data acquiring step of acquiring image data representing an image composed of a plurality of pixels each having one color component of one of N fundamental colors;

a class determining step of determining a class of the image data, from the color component of the most dense pixel of the pixels of the image data; and

an operation step of calculating the color component of each of the N fundamental colors, for one of the pixels represented by the image data, in accordance with the class determined in the class determining step.

[Claim 5] A recording medium for providing a computer-readable program for use in an image processing apparatus, said program describing:

a data acquiring step of acquiring image data representing an image composed of a plurality of pixels each having one color component of one of N fundamental colors;

a class determining step of determining a class of the image data, from the color component of the most dense pixel of the pixels of the image data; and

an operation step of calculating the color component of each of the N fundamental colors, for one of the pixels represented by the image data, in accordance with the class determined in the class determining step.

[Claim 6] An image processing apparatus comprising:

data acquiring means for acquiring first image data representing an image composed of a plurality of pixels each having one color component of one of N fundamental colors;

data generating means for generating, form the first image data, second image data of lower resolution than the first image data;

class determining means for determining a class of the second image data, from the color component of the most dense pixel of the pixels of the second image data; and

operation means for calculating a coefficient for obtaining the color component of each of the N fundamental colors, for one of the pixels represented by third image data, from the first image data acquired by the data acquiring means, the second image data generated by the data generating means and the third image data representing an image composed of a plurality of pixels each having one color component of one of N fundamental colors and based on the class determined by the class determining means.

[Claim 7] An image processing method comprising:

a data acquiring step of acquiring first image data representing an image composed of a plurality of pixels each having one color component of one of N fundamental colors;

a data generating step of generating, form the first image data, second image data of lower resolution than the first image data;

a class determining step of determining a class of the second image data, from the color component of the most dense pixel of the pixels of the second image data; and

an operation step of calculating a coefficient for obtaining the color component of each of the N fundamental colors, for one of the pixels represented by third image data, from the first image data acquired in the data acquiring step, the second image data generated by the data generating means and the third image data representing an image composed of a plurality of pixels each having one color component of one of N fundamental colors and based on the class determined by the class determining step.

[Claim 8] A recording medium for providing a computer-readable program for use in an image processing apparatus, said program describing:

a data acquiring step of acquiring first image data representing an image composed of a plurality of pixels each having one color component of one of N fundamental colors;

a data generating step of generating, form the first image data, second image data of lower resolution than the first image data;

a class determining step of determining a class of the second image data, from the color component of the most dense pixel of the pixels of the second image data; and

an operation step of calculating a coefficient for obtaining the color component of each of the N fundamental colors, for one of the pixels represented by third image data, from the first image data acquired in the data acquiring step, the second image data generated by the data generating means and the third image data representing an image composed of a plurality of pixels each having one color component of one of N fundamental colors and based on the class determined by the class determining step.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to an image processing apparatus, an image processing method and a recording medium. More particularly, the invention relates to a an image processing apparatus, an image processing method and a recording medium, which can provide images of higher resolution.

[0002]

[Prior Art]

A single-plate CCD is often used as an imaging device in digital still cameras or the like, in order to render the cameras smaller. The single-plate CCD outputs data representing n x m pixels, each having one of the three primary colors, R, G and B, as is illustrated in FIG. 1. Which color one pixel has depends on the color filter array that is placed in front of the CCD.

[0003]

A pixel arranged at the back of a G filter, for example, outputs an G-component image signal, but cannot output a R-component image signal or a B-component image signal. Likewise, a pixel outputs positioned at the back of an R filter outputs only an R-component image signal, but cannot output a G-component image signal or a B-component image signal. A pixel arranged at the back of a B filter outputs only a B-component image signal, but cannot output an R-component image signal or a G-component image signal.

[0004]

To perform various processes on the image data, however, R, G and B color components are necessary for each pixel. Classification-adaptation process, for example, is therefore performed to obtain image data equivalent to the output of a three-plate CCD, from the image data items output by the single-plate CCD. Thus, n x m R-pixel data items, n x m G-pixel data items and n x m B-pixel data items are obtained.

[0005]

[Object of the Invention]

Hitherto, the R pixels, G pixels and B pixels are independently selected as class taps, thereby to obtain image data equivalent to the output of a three-plate CCD, from the image data items output by the single-plate CCD. That is, to predict an R pixel, the R pixel is used as a class tap; to predict a G pixel, the G pixel is used as a class tap; and to predict a G pixel, the B pixel is used as a class tap.

[0006]

Consequently, only one R pixel exists for every four pixels, an only one B pixel for every four pixels, among the n x m pixels, if the color filter array incorporated in the signal-plate CCD has the Bayer arrangement as shown in FIG. 1. It is therefore impossible to effect the classification-adaptation process with high efficiency.

The present invention has been made in view of the foregoing. The object of the invention is to perform the classification-adaptation process with high efficiency.

[0007]

[Means to Solve the Problem]

The image processing apparatus as defined in claim 1 comprises: data acquiring means for acquiring image data representing an image composed of a plurality of pixels each having one color component of one of N fundamental

colors; class determining means for determining a class of the first image data, from the color component of the most dense pixel of the pixels of the image data; and operation means for calculating the color component of each of the N fundamental colors, for one of the pixels represented by the image data, in accordance with the class determined by the class determining means.

[0008]

The image processing method defined in claim 4 comprises: a data acquiring step of acquiring image data representing an image composed of a plurality of pixels each having one color component of one of N fundamental colors; a class determining step of determining a class of the image data, from the color component of the most dense pixel of the pixels of the image data; and an operation step of calculating the color component of each of the N fundamental colors, for one of the pixels represented by the image data, in accordance with the class determined in the class determining step.

[0009]

The recording medium described in claim 5 provides a computer-readable program for use in an image processing apparatus. The program describing: a data acquiring step of acquiring image data representing an image composed of a plurality of pixels each having one color component of one of N fundamental colors; a class determining step of determining a class of the image data, from the color component of the most dense pixel of the pixels of the image data; and an

operation step of calculating the color component of each of the N fundamental colors, for one of the pixels represented by the image data, in accordance with the class determined in the class determining step.

[0010]

The image processing apparatus defined in claim 6 comprises: data acquiring means for acquiring first image data representing an image composed of a plurality of pixels each having one color component of one of N fundamental colors; data generating means for generating, form the first image data, second image data of lower resolution than the first image data; class determining means for determining a class of the second image data, from the color component of the most dense pixel of the pixels of the second image data; and operation means for calculating a coefficient for obtaining the color component of each of the N fundamental colors, for one of the pixels represented by third image data, from the first image data acquired by the data acquiring means, the second image data generated by the data generating means and the third image data representing an image composed of a plurality of pixels each having one color component of one of N fundamental colors and based on the class determined by the class determining means.

[0011]

The image processing method described in claim 7 comprises: a data acquiring step of acquiring first image data representing an image composed of a

plurality of pixels each having one color component of one of N fundamental colors; a data generating step of generating, form the first image data, second image data of lower resolution than the first image data; a class determining step of determining a class of the second image data, from the color component of the most dense pixel of the pixels of the second image data; and an operation step of calculating a coefficient for obtaining the color component of each of the N fundamental colors, for one of the pixels represented by third image data, from the first image data acquired in the data acquiring step, the second image data generated by the data generating means and the third image data representing an image composed of a plurality of pixels each having one color component of one of N fundamental colors and based on the class determined by the class determining step.

[0012]

The recording medium defined in claim 8 provides a computer-readable program for use in an image processing apparatus. The program describing: a data acquiring step of acquiring first image data representing an image composed of a plurality of pixels each having one color component of one of N fundamental colors; a data generating step of generating, form the first image data, second image data of lower resolution than the first image data; a class determining step of determining a class of the second image data, from the color component of the most dense pixel of the pixels of the second image data; and an operation step of

calculating a coefficient for obtaining the color component of each of the N fundamental colors, for one of the pixels represented by third image data, from the first image data acquired in the data acquiring step, the second image data generated by the data generating means and the third image data representing an image composed of a plurality of pixels each having one color component of one of N fundamental colors and based on the class determined by the class determining step.

[0013]

In the image processing apparatus, image processing method and recording medium, which are described in claims 1, 4 and 5, respectively, the class is determined from the color component of the most dense pixel.

[0014]

In the image processing apparatus, image processing method and recording medium, which are described in claims 6, 7 and 8, respectively, a prediction coefficient is calculated from the class determined from the color component of the most dense pixel.

[0015]

[Preferred Embodiment of the Invention]

FIG. 2 illustrates the principles of processing an output of a single-plate CCD, generating image data having a density higher than the CCD output (in this embodiment, four times as high as the CCD output). As shown in FIG. 2, image

data of 2n x 2m R pixels, image data of 2n x 2m R pixels and image data of 2n x 2m B pixels are generated directly from the image data of n x m pixels, which has been output by the single-plate CCD.

[0016]

FIG. 2 shows a digital still camera designed to picking up an image, by virtue of the 1 of the operating principles described above. In the camera shown in FIG. 2, the lens 1 focuses the light reflected from the picked up image. The light is applied to the single-plate CCD 3 through an iris 2. The CCD 3 converts the input light, and the output of the CCD 3 is supplied to an AGC (Automatic Gain Control/CDS (Correlated Double Sampling) circuit 4.

[0017]

The AGC/CDS circuit 4 sets the input signal at a prescribed level, outputs the signal at the prescribed level and removes the 1/f noise generated in the CCD 3. The AGC/CDS circuit 4 performs the function of an electronic shutter, under the control of a main CPU (Central Processing Unit) 8. The signal output from the AGC/CDS circuit 4 is input to an A/D converter 5 and converted to a digital signal, which is input to an image-signal processing circuit 6. The image-signal processing circuit 6 performs, on the input signal, a defect-eliminating process, a digital clamping process, a white-balance adjusting process, a gamma-correction process, an interpolation process using the classification-adaptation process. A memory 12 is connected to the image-signal processing circuit 6. The memory

12 stores image data, whenever necessary, while the image-signal processing circuit 6 is performing these processes.

[0018]

A timing generator (TG) 7 is controlled by the main CPU 8. It generates various timing signals. The timing signals are output to the CCD 3, AGC/CDS circuit 4, A/D converter 45, main CPU 8 and the like.

[0019]

A motor 9 drives the iris 2 under the control of the main CPU 8. The amount of light applied from the lens 1 to the CCD 3 is controlled. A motor 10 which is controlled by the main CPU 8 controls the lens 1, to control the state of the focus for the CCD3 of the lens 1. Under the controlled by the main CPU 8, a light-emitting section 11 applies a prescribed amount of flash light to the object of photography.

[0020]

A storage-medium interface (I/F) 13 is provided. The interface 13 supplies the image data output from the image-signal processing circuit 6, whenever necessary, thus storing the image data into the memory 14. After effecting a prescribed interface process, the interface 13 supplies the image data to a storage medium 15, storing the image data therein. The user can easily inserted the storage medium 15 into the digital still camera and remove the same therefrom.

[0021]

A controller 16 is provided to control the image-signal processing circuit 6 and the storage-medium interface 13 under the control of the main CPU 8. Various user commands are input from a terminal 20 to the main CPU 8. A power-supply section 17 is provided, which incorporates a battery 18 and a DC/DC converter 19. The DC/DC converter 19 converts the power supplied from the battery 18 to a DC voltage of a predetermined value. The DC voltage is applied to the components of the camera. The battery 18 is a rechargeable one. The user can insert the battery 18 into and remove it from the digital still camera.

[0022]

The process of picking up the image and storing the data representing the image of the object into the storage medium 15 will be described, with reference to the flowchart of FIG. 3.

In Step S1, the lens 1 collects the light reflected from the object. The light is applied through the iris 2 to the CCD 3. At this time, the main CPU 8 controls the motor 9, driving the iris 2. The amount of light applied to the CCD 3 is thereby adjusted to the predetermined value. The main CPU 8 controls a motor 10, too. The motor 10 adjusts the position of the lens 1, accomplishing focus control.

[0023]

The main CPU 8 determines whether the terminal 20 has received a signal that is generated when the user operates the release button (not shown) provided on

the camera. If the user has not operated the release button, the operation returns to Step S1, which is repeated. If it is determined in Step S2 that the release button has been operated, the main CPU 8 drives the light-emitting section 11, which emits flash light. The flash light illuminates the picked up image. At this time, the main CPU 8 controls the timing generator 7, which generates various timing signals. In Step S3, the CCD 3 converts the light reflected from the image to an electric signal in synchronism with the timing signal supplied from the timing generator 7. The electric signal is output to the AGC/CDS circuit 4.

[0024]

In Step S4, the AGC/CDS circuit 4 removes the 1/f noise component of the signal input from the CCD 3. The signal, now having no noise component, is output as a level having a prescribed level, to the A/D converter 5. In Step S5, the A/D converter 5 converts the signal output from the AGC/CDS circuit 4, to a digital image signal. The digital image signal is output to the image-signal processing circuit 6. In Step S6, the image-signal processing circuit 6 stores the image signal into the memory 12, if necessary, and processes the image signal. The image signal, thus processed, is output to the storage-medium interface 13. The storage-medium interface 13 stores the image signal input from the image-signal processing circuit 6 and stores the same, if necessary, into the memory 14. After performing the interface process, the interface 13 supplies the image signal to the storage medium 15. In Step S7, the storage medium 15 stores

the image signal supplied to it.

[0025]

FIG. 4 shows an example of the image-signal processing circuit 6. The image signal, which has been generated by the single-plate CCD 3 and input from the A/D converter 5, is input to a defect-correcting circuit 31. The defect-correcting circuit 31 performs the process of eliminating a defective part of the image signal, which corresponds to a pixel or pixels of the CCD 3 that fail to respond to the input light or to a pixel or pixels that always hold an electric charge.

[0026]

The A/D converter 5 shifts the signal value a little in the positive direction, in order to prevent the negative value from being cut. A clamping circuit 32 shifts the signal output from the defect-correcting circuit 31, back in the opposite direction. A white-balancing (WB) circuit 33 corrects the gains of the R, G and B signals input from the clamping circuit 32. A gamma-correcting circuit 34 corrects the value of the signal input from the white-balancing circuit 33, in accordance with a gamma curve.

[0027]

An interpolating section 35 is provided, which performs a classification-adaptation process, thereby interpolating the signal output from the gamma-correcting circuit 34. The interpolating section 35 has an ADRC (Adaptive Dynamic Range Control) process circuit 41 that processes the signal

input from the gamma-correcting circuit 34. The ADRC process circuit 41 performs an ADRC process on the signal value of the class tap contained in the input signal. A classification circuit 42 determines a class from the signal value of the class tap ADRC-processed by the ADRC process circuit 41, thereby outputting a class number. An adaptation process circuit 43 reads from a coefficient memory 44 the coefficient that corresponds to the class input from the classification circuit 42. The circuit 43 multiplies the coefficient by the pixel value of a prediction tap for the image signal input through the ADRC process circuit 41 and classification circuit 42, thereby calculating a necessary pixel value.

[0028]

A correction circuit 36 is provided, which performs correction, such as edge correction, on the signal input from the adaptation process circuit 43 of the interpolating section 35, thus improving the visual feature of the image. An RGB matrix circuit 37 outputs the RGB signal input from the correction circuit 36 without processing these signals. Alternatively, the circuit 37 multiplies this signal by a prescribed conversion matrix, thereby converting the signals to a YUV signal or the like. The YUV signal or the like is output from the circuit 37.

[0029]

How the image-signal processing circuit 6 operates will be explained, with reference to the flowchart of FIG. 5. In Step S11, the defect-correcting circuit 31 corrects a defective pixel or pixels, if any, contained in the image signal input from

the A/D converter 5. For example, the circuit 32 replaces any pixel that does not respond to light or any pixel that always has an electric charge, with the average value of the neighboring pixels. In Step S12, the clamping circuit 32 performs a clamping process on the signal input from the defect-correcting circuit 31, thereby to correct the offset value set in the A/D converter 5. In Step S13, the white-balancing circuit 33 adjusts the levels of the R signal, G signal and B signal to such levels that these signals may represent white. In Step S14, the gamma-correcting circuit 34 carries out the gamma-correction process.

[0030]

In Step S15, the ADRC process circuit 41 divides the input signal to p x q blocks. In Step S16, the circuit 41 extracts a class tap for each block and performs the ADRC process on the class tap.

[0031]

In Step S17, the classification circuit 42 performs the classification process on the data input from the ADRC process circuit 41. That is, the circuit 42 determines the class that corresponds to the value obtained by ADRC-processing the class tap. The class thus determined is output to the adaptation process circuit 43. In Step S18, the adaptation process circuit 43 reads the prediction coefficient corresponding to the class input from the classification circuit 42, from the coefficient memory 44, and multiplies the prediction coefficient by the corresponding prediction tap, thereby generating the data representing a predicted

pixel.

[0032]

Next, in Step S19, the interpolating section 35 determines whether the interpolation has been effected on all blocks. If any block has not been subjected to the interpolation, the operation returns to Step S16. In this case, Steps S16 et seq. are repeated.

[0033]

If it is determined in Step S19 that all blocks have been subjected to the interpolation, the operation advances to Step S20. In Step S20 the correction circuit 36 carries out correction, such as edge correction, on the input signal. In Step S21, the RGB matrix circuit 37 performs an operation, if necessary, to convert the RGB data to YUB data (that is, to convert the input data to a color space), and outputs the result of conversion.

Specific examples of the class tap and prediction tap will be described. As shown in FIG. 6, for example, a B pixel may be the pixel to be predicted. Then, as shown in FIG. 7, the class tap is composed of eight G pixels. Of these eight G pixels, four are arranged above, below, to the left of and to the right of, the pixel to be predicted, respectively. Two are arranged at upper-left and lower-left positions with respect to the G pixel on the left of the pixel to be predicted, and the remaining two are arranged at upper-right and lower-right positions with respect to the G pixel on the right of the pixel to be predicted. In this case, the prediction

tap is composed of 5 x 5 pixels, including R pixels, G pixels and B pixels, as illustrated in FIG. 8, with a B pixel located at the center of the 5 x 5 matrix.

[0034]

An R pixel may be the pixel to be predicted as is illustrated in FIG. 9. In this case, the class tap is composed of eight G pixels as shown in FIG. 10. Of these eight G pixels, four are arranged above, below, to the left of and to the right of, the R pixel to be predicted, respectively. Two are arranged at upper-left and lower-left positions with respect to the G pixel on the left of the pixel to be predicted, and the remaining two are arranged at upper-right and lower-right positions with respect to the G pixel on the right of the pixel to be predicted. The prediction tap in this case is composed of 25 pixels, including R pixels, G pixels and B pixels, as illustrated in FIG. 11, with an R pixel located at the center of the 5 x 5 matrix.

[0035]

Further, a G pixel may be the pixel to be predicted as is illustrated in FIG. 12. In this case, the class tap is composed of nine G pixels as shown in FIG. 13. More precisely, the class tap shown in FIG. 13 is composed of the G pixel to be predicted, four G pixels arranged above, below, to the left of and to the right of, the G pixel to be predicted, respectively, two G pixels arranged above and below the G pixel to be predicted and spaced therefrom by a R pixel, and two G pixels arranged to left and right of the G pixel to be predicted and spaced therefrom by a B pixel.

The prediction tap in this case is composed of 5 x 5 pixels that have R, G and B color components. Of these pixels, one G pixel is to be predicted, and the remaining pixels surround the G pixel, as is illustrated in FIG. 14.

[0036]

A luminance signal Y is generated from the signal values for R, G and B, as in indicated by the following equation:

[0037]

$$Y = 0.30R + 0.59G + 0.11B$$

As seen from this equation, the G component more influences the luminance signal Y than the other color components. Therefore, as shown in FIG. 6, G pixels are arranged more densely than the R and B pixels in the Bayer arrangement.

[0038]

In view of this, it may be possible to effect the classification-adaptation process with higher precision if the class tap is composed of only G pixels of the image signal.

[0039]

FIG. 15 shows a learning apparatus that acquires prediction coefficients to be stored in the coefficient memory 44 and to be used in the adaptation process described above. In the learning apparatus 61, digital image data is supplied, as a teacher image, to an extraction circuit 71 and a teacher-image block generating

circuit 75. The teacher image has, for example, a density four times as high as the original image data. The extraction circuit 71 extracts pixels from the teacher-image data, on the assumption that color filters, each having a magnification opposite to the one the photographing system should have. As a result, the extraction circuit 71 outputs student image data that is equivalent to the image data the single-place CCD 3 has generated.

[0040]

The image data representing the student image is input to a student-image block generating circuit 72. The student-image block generating circuit 72 extracts the class tap to be used in the classification process and prediction tap to be used in prediction process, from the student-image data generated by the extraction section 71, while referring to the relation between the teacher-image signal and the predicted pixel for each block. An ADRC process circuit 73 performs an ADRC process on the prediction tap of the pixels input from the student-image block generating circuit 72, and outputs the pixels to a classification circuit 74. The classification circuit 74 determines the class from the value of the class tap that has been ADRC-processed by the ADRC process circuit 73. The class is output to an operating circuit 76. The operating circuit 76 receives the image data of the prediction tap from the student-image block generating circuit 72 through the ADRC process circuit 73 and classification circuit 74.

[0041]

The teacher-image block generating circuit 75 extracts the predicted pixel from the teacher-image data, while referring to the relation between the class tap in the student image. The predicted pixel extracted is output to the operating circuit 76. The operating section 76 carries out an operation on the class number supplied from the classification circuit 74, while maintaining the relation between the prediction tap supplied from the classification circuit 74 and the predicted image supplied from the teacher-image block generating circuit 75. Thus, the operating circuit 76 generates the data of a normal equation. The data of the normal equation, generated by the operating section 76, is stored into a learned data memory 77. The memory 77 sequentially stores the matrix coefficients of the normal equation, supplied from the operating circuit 76. Another operating circuit 78 is provided, which performs least square method, thus solving the normal equation by using the matrix of the normal equation stored in the learned data memory 77. Prediction coefficients are thereby calculated for one class. The prediction coefficients are stored into a coefficient memory 79.

[0042]

How the learning apparatus 61 functions will be explained with reference to the flowchart of FIG. 16. In Step S31, the teacher-image block generating circuit 75 converts the input teacher-image signal to a block, thus extracting a predicted pixel. The predicted pixel is output to the operating circuit 76. In Step S32, the extraction section 71 extracts the teacher-image data, thereby generating

student-image data corresponding to the image data output by the single-plate CCD 3. The teacher-image data is output to the student-image block generating circuit 72. In Step S33, the student-image block generating circuit 72 converts the input student-image data to a block. The circuit 72 generates a class tap and a prediction tap for the block.

[0043]

In Step S34, the ADRC process circuit 73 carries out the ADRC process on the prediction tap supplied from the student-image block generating circuit 72. In Step S35, the classification circuit 74 determines a class code on the basis of the class tap supplied from the ADRC process circuit 73.

[0044]

In Step S36, the operating circuit 76 generates the normal equation for the class number supplied from the classification circuit 74, on the basis of the prediction tap supplied from the classification circuit 74 and the predicted image supplied from the teacher-image block generating circuit 75. In Step S37, it is determined whether the operating circuit 76 has finished processing all blocks or not. If there are any blocks not processed yet, the operation returns to Step S36. In this case, Step S36 et seq. are repeated. If it is determined in Step S37 that all blocks have been processed, the operation goes to Step S38. In Step S38, the operating circuit 78 solves the normal equation stored in the learned data memory 77 by means of, for example, the least square method. In Step S39, it is

determined whether or not the operating circuit 78 has solved the normal equation for all classes. If the equation has not been solved for any classes, the operation returns to Step S38. In this case, Step S38 et seq. are repeated.

[0045]

If it is determined in Step S39 that the normal equation has been solved for all classes, the operation is terminated. The prediction coefficients thus obtained are supplied to the coefficient memory 79 and stored therein. The prediction coefficients are then stored into the coefficient memory 44 shown in FIG. 4.

[0046]

In the embodiment, the color filters of the CCD 3 are of the Bayer arrangement illustrated in FIG. 17(A). Instead, the color filters may be of interline arrangement shown in FIG. 17(B), a G-stripe, RB chessboard arrangement shown in FIG. 17(C), a G-stripe, RB perfect chessboard arrangement depicted in FIG. 17(D), a stripe arrangement illustrated in FIG. 17(E), a slant stripe arrangement shown in FIG. 17(F), or a primary color-difference arrangement illustrated in FIG. 17(G).

[0047]

The filters provided for the CC3 may be complement-color filters, not primary-color filters. In this case, each pixel has a value selected from yellow (Ye), cyan (Cy), magenta (Mg) and green (G), and the color filter may be of a field interleave arrangement or a strip arrangement, both shown in FIG. 18.

[0048]

In order to evaluate the operating efficiency of the embodiment described above, the inventors conducted simulation, using a color-filter array of the Bayer arrangement.

[0049]

An image signal equivalent to an output of a three-plate CCD was subjected to an extraction operation in which the magnification of the classification-adaptation process was applied and the positional relation of pixels was taken into account. An image signal equivalent to an output of the single-plate CCD was thereby generated. The output of the single-plate CCD was converted to an image signal having twice as many pixels in both the low direction and the column direction, by means of a classification-adaptation process in which the prediction coefficients for the CCD output were utilized.

[0050]

Further, the nine high-vision images of the IT standard were used as teacher images. The class taps and prediction taps used were those illustrated in FIG. 7, FIG. 8, FIG. 10 and FIGS. 13 and 14.

[0051]

The simulation resulted in an image that was more sharp at edges and had a higher resolution than in the case where the class tap applied to predict an R pixel (alternatively, a G signal or a B signal) is a pixel that has R, G and B components

mixed together. Simulation was conducted by means of linear interpolation, not classification-adaptation process. The image generated by classification process was found superior to the image signal provided by linear interpolation in terms of resolution and S/N ratio.

[0052]

In the embodiment described above, the output of the single-plate CCD is converted to an image that is equivalent to one output by a three-plate CCD. Nevertheless, the present invention can be applied to generate image data of any other density.

[0053]

Moreover, the present invention can be applied not only to a digital still camera, but also to a video camera and any other type of an image-processing apparatus.

[0054]

The recording medium storing the computer program is presented to users, in the form of a magnetic disk, a CD-ROM, solid memory or the like. Instead, the program can be transmitted to users through networks and digital-communications satellites.

[0055]

[Advantageous Effect of the Invention]

As has been described, the class is determined from the color component of

the most dense pixel in the image processing apparatus, image processing method and recording medium, which are described in claims 1, 4 and 5, respectively. The N fundamental color components are calculated from the class thus determined. Therefore, image data can be generated with high precision.

[0056]

In the image processing apparatus, image processing method and recording medium, which are described in claims 6, 7 and 8, respectively, coefficients for obtaining N fundamental color components are calculated from the third image data representing an image that is composed of pixels having the N fundamental color components, in accordance with the class determined from the color component of the most dense pixel. Hence, it is possible to provide coefficients that help to generate image data with high precision.

[Brief Description of the Drawings]

[FIG. 1]

A diagram illustrating the principles of generating an output equivalent to one generated by a three-plate CCD.

[FIG. 2]

A block diagram of a digital still camera according to the present invention.

[FIG. 3]

A flowchart explaining the operation of the digital still camera shown in FIG. 2.

[FIG. 4]

A block diagram showing the image-signal processing circuit 6 of the camera shown in FIG. 2.

[FIG. 5]

A flowchart explaining how the image-signal processing circuit of FIG. 4 operates.

[FIG. 6]

A diagram for explaining a predicted pixel.

[FIG. 7]

A diagram illustrating a class tap.

[FIG. 8]

A diagram explaining a prediction tap.

[FIG. 9]

A diagram showing a predicted pixel

[FIG. 10]

A diagram depicting a class tap.

[FIG. 11]

A diagram explaining a prediction tap.

[FIG. 12]

A diagram showing a predicted pixel.

[FIG. 13]

A diagram depicting a class tap.

[FIG. 14]

A diagram showing a prediction tap.

[FIG. 15]

A block diagram of a learning apparatus that generates prediction coefficients to be stored into the coefficient memory 44 shown in FIG. 4.

[FIG. 16]

A flowchart explaining the operation of the learning apparatus shown in FIG. 15.

[FIG. 17]

A diagram illustrating an arrangement of primary-color filters.

[FIG. 18]

A diagram showing an arrangement of complement-color filters.

[Explanation of Referenced Numerals]

1 lens ; 3 CCD ; 6 image-signal processing circuit ;

8 main CPU ; 31 defect-correcting circuit ; 35 interpolating section ;

36 correction circuit ; 41 ADRC process circuit ;

42 classification circuit ; 43 adaptation process circuit ;

44 coefficient memory ; 61 learning apparatus ; 71 extraction circuit ;

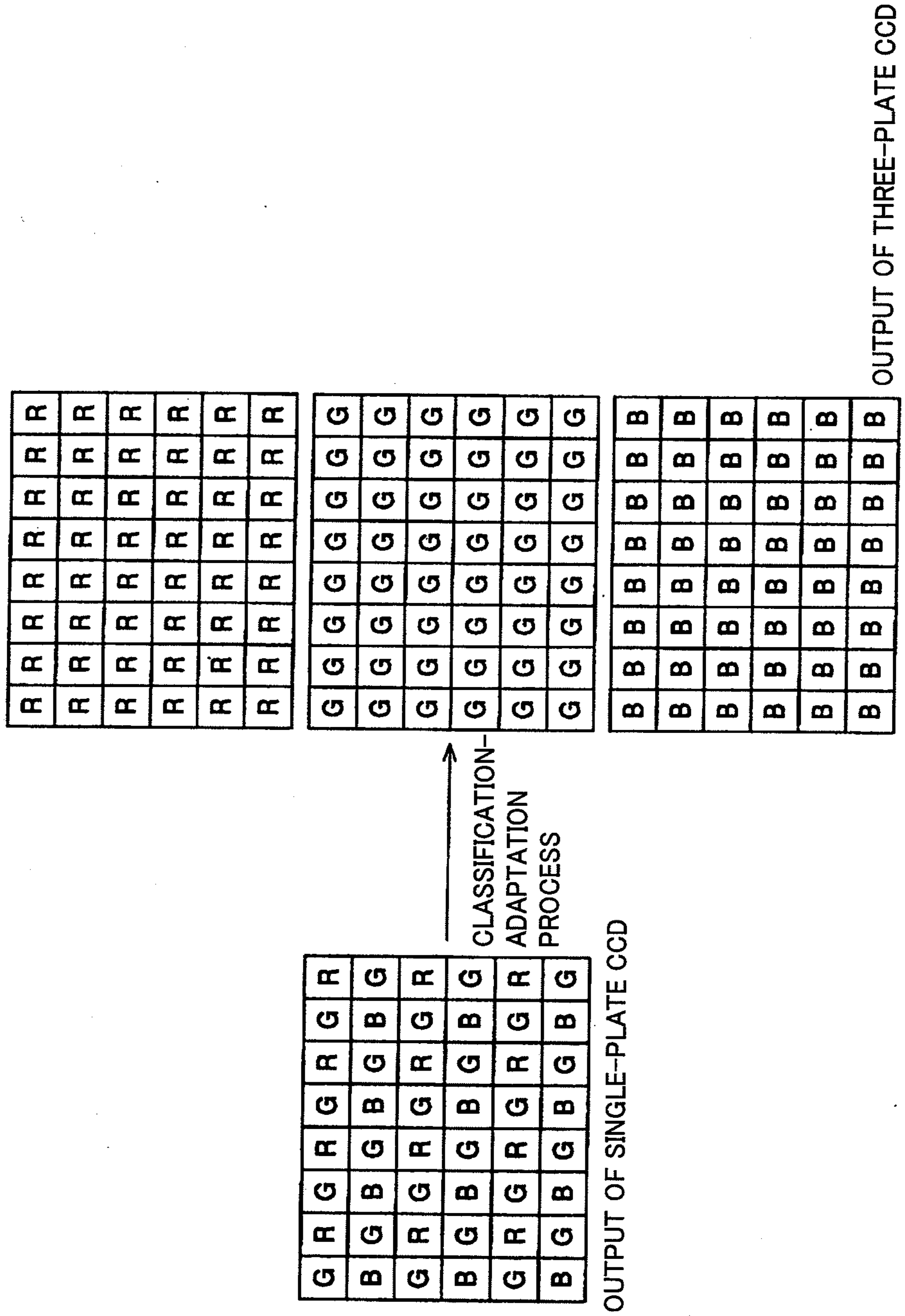
72 student-image block generating circuit ; 73 ADRC process circuit ;

74 classification circuit ; 75 teacher-image block generating circuit ;

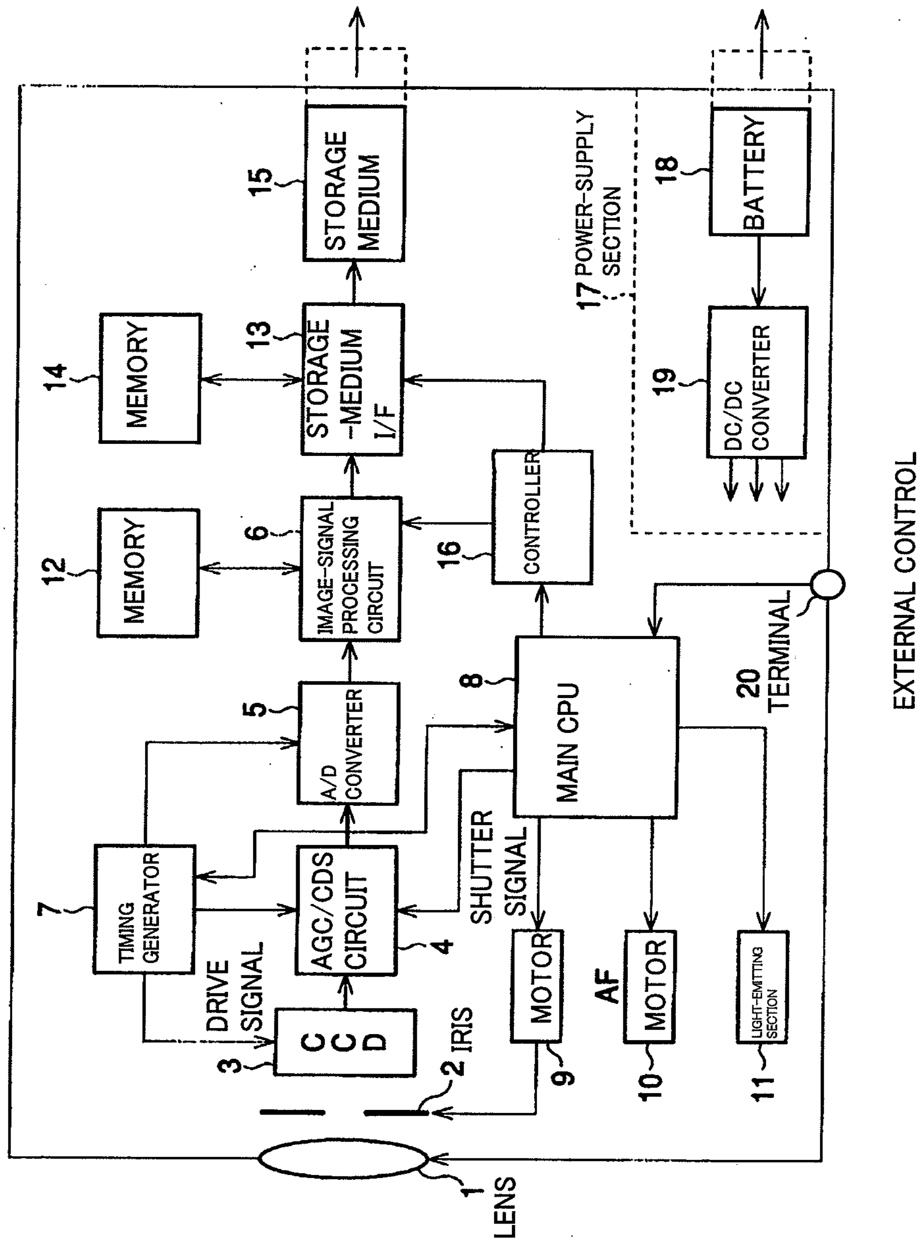
76 operating circuit ; 77 learned data memory ; 78 operating circuit ;
79 coefficient memory

[Document Name] DRAWING

[FIG. 1]

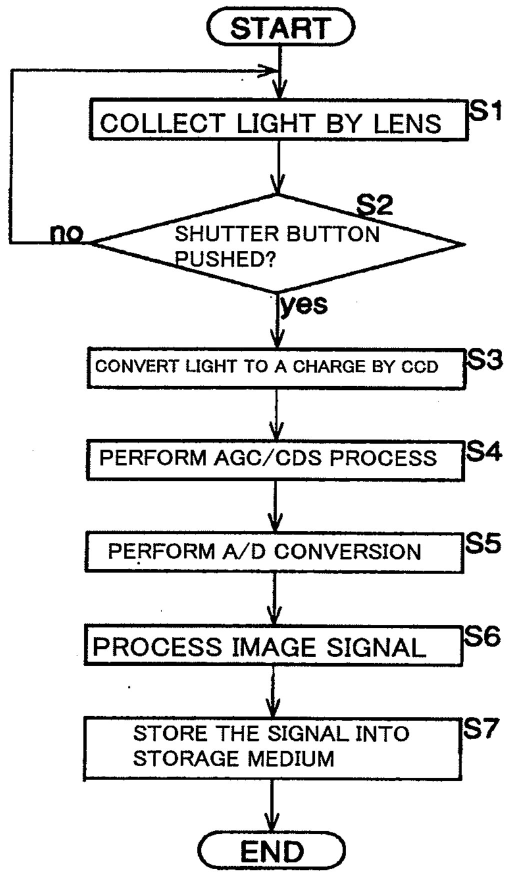


[FIG. 2]



LENS
1
IRIS
2
CCD
3
AGC/CDS CIRCUIT
4
A/D CONVERTER
5
IMAGE-SIGNAL PROCESSING CIRCUIT
6
TIMING GENERATOR
7
DRIVE SIGNAL
MAIN CPU
8
SHUTTER SIGNAL
MOTOR
9
AF
MOTOR
10
LIGHT-EMITTING SECTION
11
MEMORY
12
STORAGE -MEDIUM I/F
13
MEMORY
14
STORAGE MEDIUM
15
CONTROLLER
16
17 POWER-SUPPLY SECTION
BATTERY
18
DC/DC CONVERTER
19
20 TERMINAL
EXTERNAL CONTROL

[FIG. 3]


START
COLLECT LIGHT BY LENS
S1
S2
no
SHUTTER BUTTON PUSHED?
yes
CONVERT LIGHT TO A CHARGE BY CCD
S3
PERFORM AGC/CDS PROCESS
S4
PERFORM A/D CONVERSION
S5
PROCESS IMAGE SIGNAL
S6
STORE THE SIGNAL INTO STORAGE MEDIUM
S7
END

[FIG. 4]

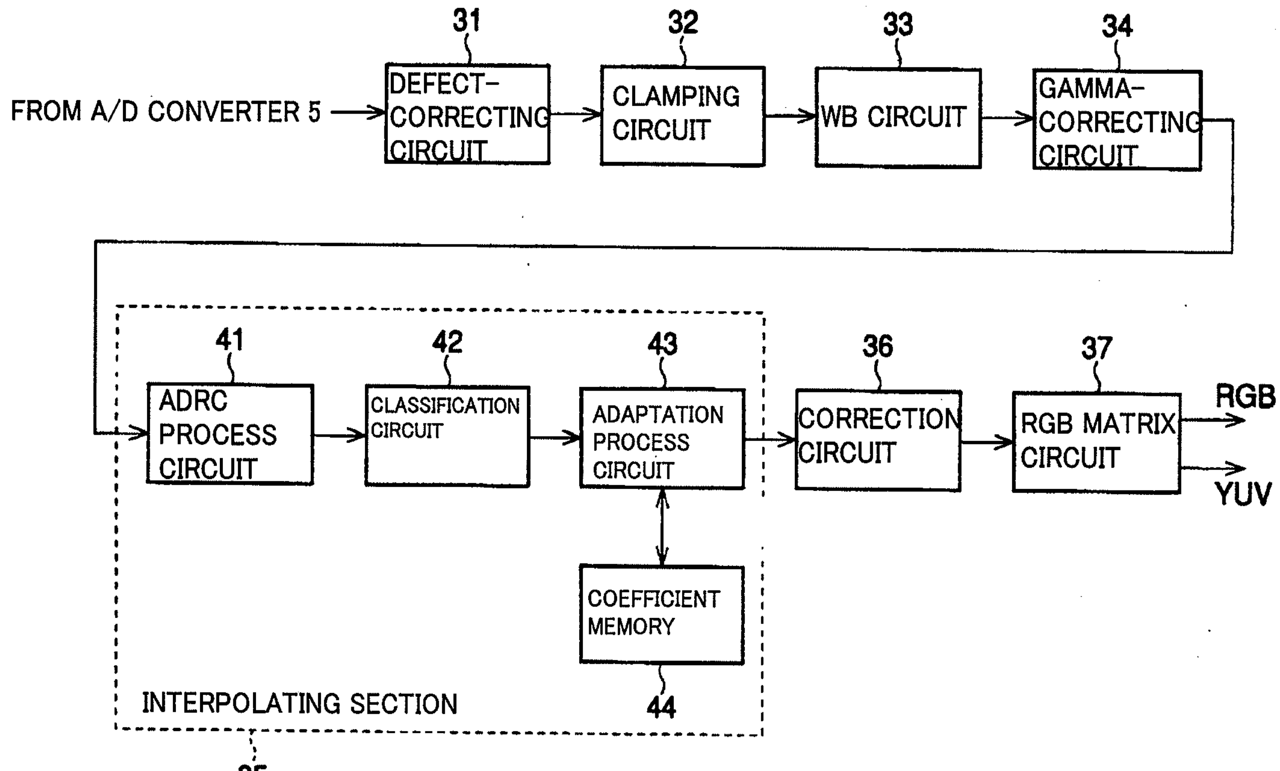
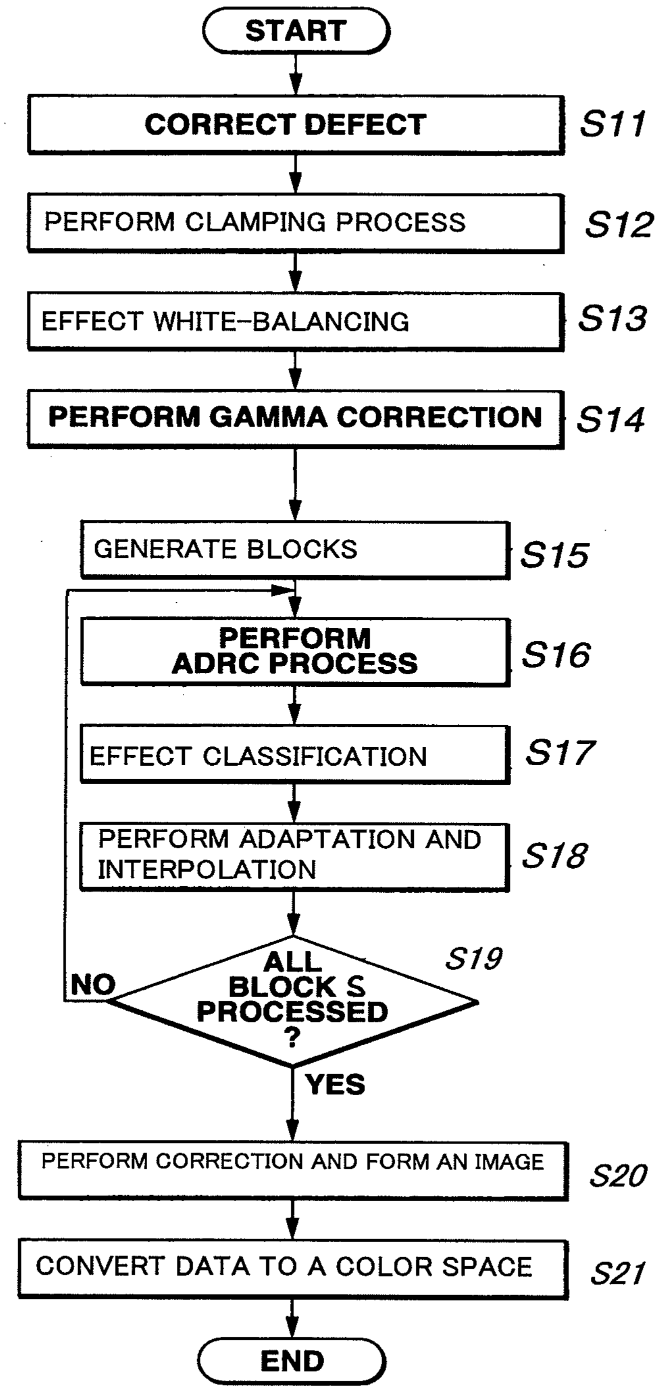


IMAGE-SIGNAL PROCESSING CIRCUIT 6

[FIG. 5]


START
CORRECT DEFECT
S11
PERFORM CLAMPING PROCESS
S12
EFFECT WHITE-BALANCING
S13
PERFORM GAMMA CORRECTION
S14
GENERATE BLOCKS
S15
PERFORM ADRC PROCESS
S16
EFFECT CLASSIFICATION
S17
PERFORM ADAPTATION AND INTERPOLATION
S18
ALL BLOCK S PROCESSED ?
S19
NO
YES
PERFORM CORRECTION AND FORM AN IMAGE
S20
CONVERT DATA TO A COLOR SPACE
S21
END

[FIG. 6]

R	G	R	G	R	G	R	G
G	B	G	B	G	B	G	B
R	G	R	G	R	G	R	G
G	B	G	$\boxed{B}$	G	B	G	B
R	G	R	G	R	G	R	G
G	B	G	B	G	B	G	B
R	G	R	G	R	G	R	G
G	B	G	B	G	B	G	B

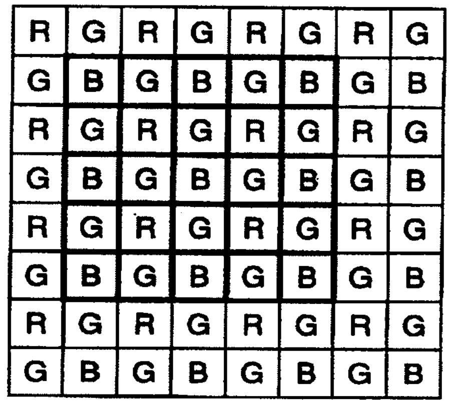
PREDICTED PIXEL

[FIG. 7]

R	G	R	G	R	G	R	G
G	B	G	B	G	B	G	B
R	$\boxed{G}$	R	$\boxed{G}$	R	$\boxed{G}$	R	G
G	B	$\boxed{G}$	B	$\boxed{G}$	B	G	B
R	$\boxed{G}$	R	$\boxed{G}$	R	$\boxed{G}$	R	G
G	B	G	B	G	B	G	B
R	G	R	G	R	G	R	G
G	B	G	B	G	B	G	B

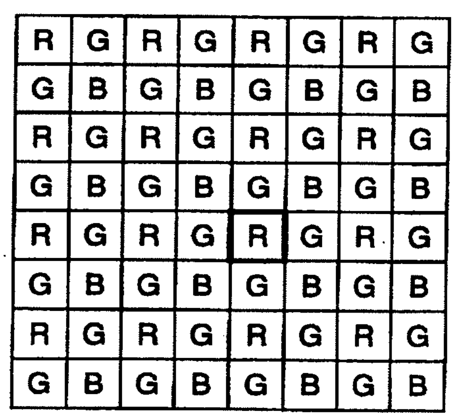
CLASS TAP

[FIG. 8]



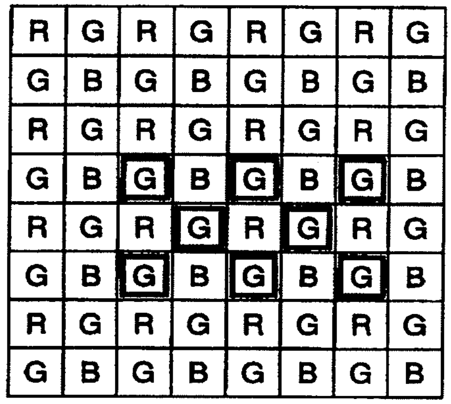
PREDICTION TAP

[FIG. 9]



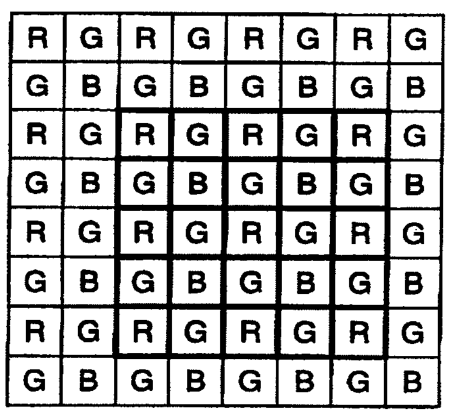
PREDICTED PIXEL

[FIG. 10]



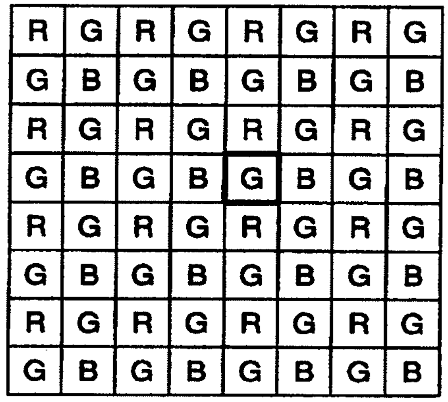
CLASS TAP

[FIG. 11]



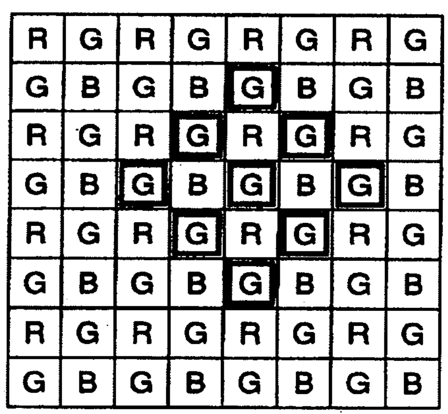
PREDICTION TAP

[FIG. 12]



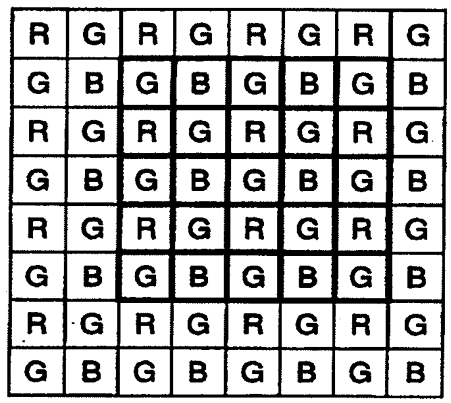
PREDICTED PIXEL

[FIG. 13]



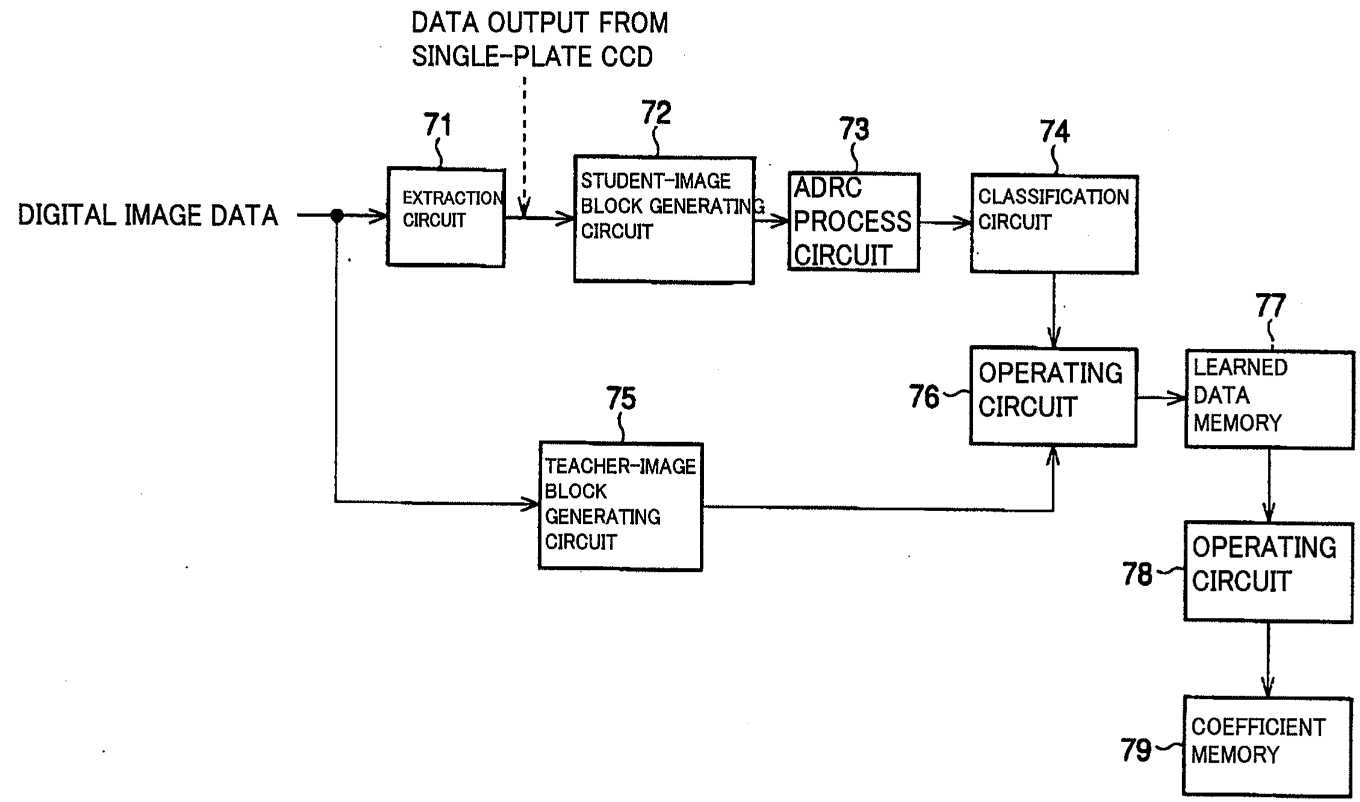
CLASS TAP

[FIG. 14]



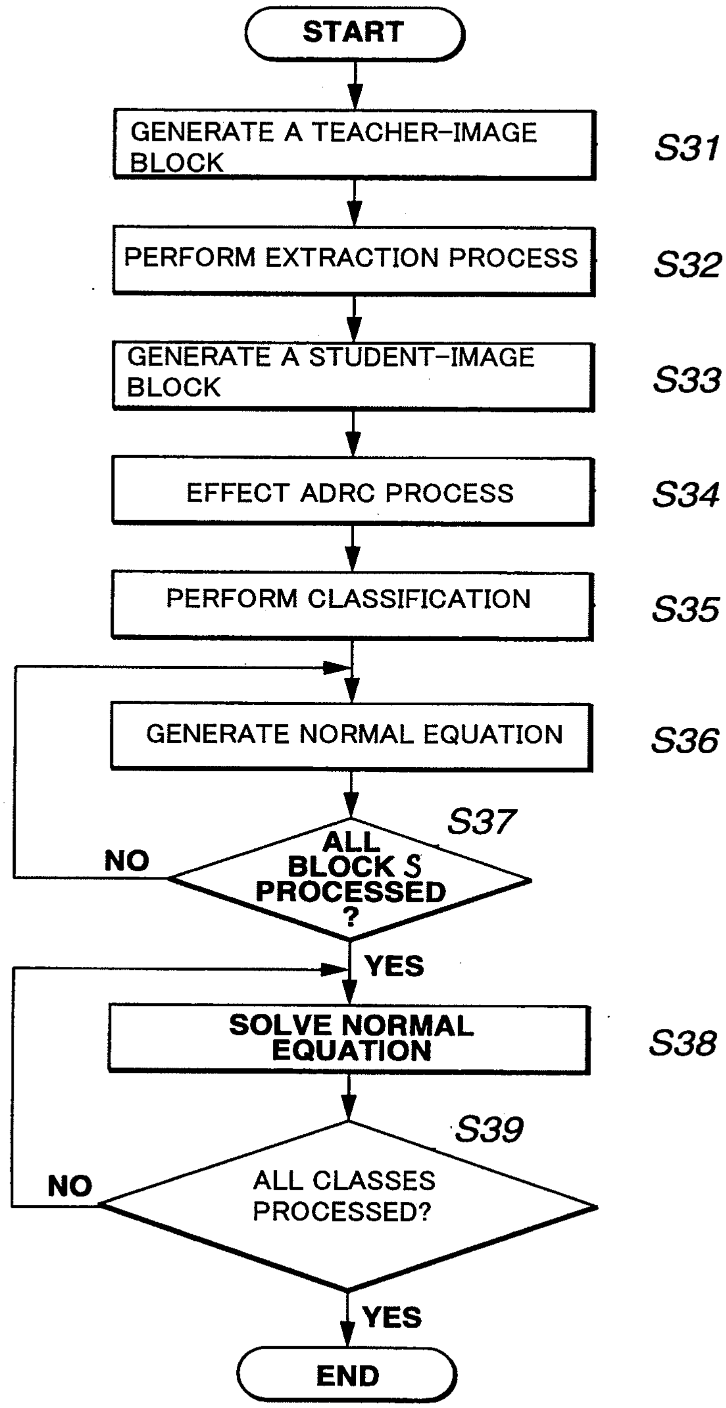
PREDICTION TAP

[FIG. 15]



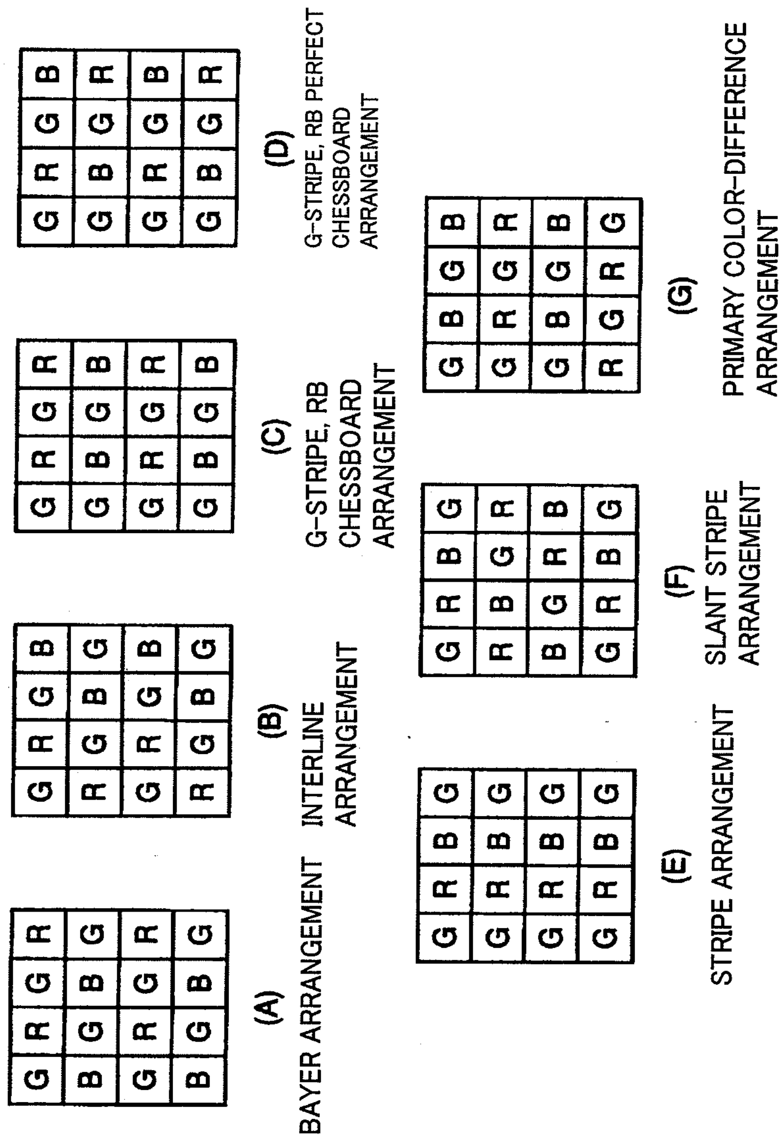
LEARNING APPARATUS 61

[FIG. 16]



START
GENERATE A TEACHER-IMAGE BLOCK
S31
PERFORM EXTRACTION PROCESS
S32
GENERATE A STUDENT-IMAGE BLOCK
S33
EFFECT ADRC PROCESS
S34
PERFORM CLASSIFICATION
S35
GENERATE NORMAL EQUATION
S36
S37
ALL BLOCKS PROCESSED ?
NO
YES
SOLVE NORMAL EQUATION
S38
S39
ALL CLASSES PROCESSED?
NO
YES
END

[FIG. 17]


(A)
BAYER ARRANGEMENT
(B)
INTERLINE ARRANGEMENT
(C)
G-STRIPE, RB CHESSBOARD ARRANGEMENT
(D)
G-STRIPE, RB PERFECT CHESSBOARD ARRANGEMENT
(E)
STRIPE ARRANGEMENT
(F)
SLANT STRIPE ARRANGEMENT
(G)
PRIMARY COLOR-DIFFERENCE ARRANGEMENT

[FIG. 18]

G	C	G	C
G	Y	G	Y
G	C	G	C
Y	G	Y	G

(A)

FIELD INTERLEAVE ARRANGEMENT

Y	G	C	Y
Y	G	C	Y
Y	G	C	Y
Y	G	C	Y

(B)

STRIP ARRANGEMENT

[Document Name] ABSTRACT

[Abstract]

[Problems to be Solved]

To generate a three-plate CCD output of high precision from an output of a single-plate CCD.

[Means to Solve the Problems]

Classification-adaptation process is performed on an output of a single-plate CCD, which represents pixels each having one of the three primary colors R, B and G, thereby to provide an output which is equivalent to one generated by a three-plate CCD and which represents pixels each having R, G and B components. Only the G component having the highest density is used as a class tap in the classification-adaptation process.

[Selected Figure] FIG. 7